# Comparing Water Quality Monitoring Requirements in European and United States Laws

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**Abstract**

Water quality management, in both Europe and the United States (US), is undergoing change. In Europe, the European Union (EU) issued a Water Framework Directive (WFD) in October 2000 that establishes a common approach to water management across Europe, including specific guidance on how monitoring is to be conducted (Directive 2000/60/EC of the European Parliament). In the US, lawsuits challenging the fundamental approach to water quality-based management are leading to a careful examination of how data and information are related to management decision-making. In the US, the Clean Water Act (CWA) guides water quality management, but does not appear to provide guidance on how to obtain the water quality data and information that is to support management decision-making. The purpose of this paper is to compare the monitoring guidance provided by the WFD with that of the CWA. The differences in legal descriptions of required monitoring assist in understanding the need for consistent and comparable data and information from monitoring in support of management. Legal requirements for monitoring in each law are examined along with the monitoring/information implications embedded in management's power and functions. Both laws appear weak in specifying connections between monitoring and the information needed for management, but the WFD provides guidance on how to collect samples, what measurements to make, and where to make them as well as how to present monitoring information to the decision making bodies.

## Introduction

The intense focus on water quality monitoring, in a new European Union (EU) directive and in legal actions in the United States (US), is forcing designers of water quality monitoring systems to carefully examine the monitoring system design process and be more accountable for information results. The legal establishment appears to be increasingly deploring the lack of management-oriented information produced by water quality monitoring. The WFD goes so far as to specify specific constituents to be measured and the frequency of measurement, for example. When bills were introduced into Congress in the early 1990s, to reauthorize the CWA, sections addressing enhanced focus on water quality monitoring were inserted (none of the bills introduced in Congress passed). Since, there have been many calls in the US for monitoring to produce water quality data and information that is fair, consistent, comparable, and, therefore, relevant to management decision-making (Intergovernmental Task Force on Monitoring, 1995; General Accounting Office, 2000; Griffiths et al, 2001; Methods and Data Comparability Board, 2001; and Ward, 2002). The WFD provides additional guidance on monitoring design, thus suggesting to the authors that water quality laws are moving toward specifying how information to support implementation of a law is to be obtained. Such legal attempts to provide technical and scientific guidance are instructive to monitoring system designers.

The purpose of this paper is to compare the monitoring requirements/guidance provided in the recently approved EU WFD to that specified in the US CWA. In meeting this purpose, the technical and scientific guidance provided in water quality laws will be examined.

For purposes of comparing laws with respect to monitoring, the paper first presents a definition of monitoring, from a management perspective (as opposed to a research perspective often associated with measuring water quality conditions). The monitoring definition provides a means to organize the comparisons of monitoring guidance provided in the laws.

**Scope**

Water quality laws and directives, in defining societal water quality goals, management powers and functions, and specific information reporting requirements, require extensive and detailed water quality data and information. Thus, the review contained in this paper must be selective and focused. A thorough review of all laws and regulations is beyond the scope of the paper. In fact, many of the regulations needed to implement the WFD are currently under development and, thus, are not available for comparison purposes.

The interpretations of law provided in the paper come from the perspective of seeking to define monitoring design criteria and guidance from an information goal point-of-view. No attempt is made to interpret the CWA and WFD in any other context.

Acquiring information about water quality conditions, for purposes of 'managing' water quality, is often narrowly equated with measuring water quality conditions for purposes of understanding processes or 'testing' for water quality standard exceedences at a specific sampling site – i.e. 'researching' water quality conditions. On the other hand, modern water quality management needs information about water quality conditions from multiple levels, including consistent and comparable information across time and space, covering time scales of years/decades and space scales of states and nations. Employing monitoring methods that are heavily influenced by traditional science's peer review process, without considering the wide range of information needs of management, may not serve the broader, policy-making and accountability, needs of water quality management (Ward, 2002).

With the above in mind, this paper will not attempt to address the information needs of management normally associated with understanding processes over limited time and space, such as might be conducted for a Total Maximum Daily Load (TMDL) *computation* under Section 303 of the United State's CWA. Rather, the focus will be on reporting water quality conditions, using consistent and comparable information, over large time and space scales, such as the reporting requested under Section 305(b) of the CWA or in the Section 303 TMDL *listing* of stream segments not meeting standards. This distinction of the type of management information addressed in this paper, hopefully, helps focus the definition of a monitoring system for purposes of comparing legal monitoring guidance. The adjective 'ambient' is often used to describe the form of monitoring addressed in this paper.

**Defining Monitoring for Management Purposes**

To compare monitoring specifications in the CWA and WFD, there first must be a definition of monitoring to form the basis of the comparison. Thus, arises the question: What constitutes 'monitoring'? To approach answering this question, a process of water quality monitoring, to obtain comparable and consistent information for management, will be established. The assumption behind defining a monitoring process is that each step of monitoring must exist and carefully connect to the other steps if management relevant information is to be produced.

In recent years there have been a number of efforts to define ambient monitoring systems employed in the support of management decision-making. Ward et al (1990) define ambient monitoring as consisting of six sequential, operational activities that follow the flow of information: (1) sampling, (2) laboratory analysis, (3) data management, (4) data analysis, (5) reporting, and (6) information utilization. The first three activities

generate data while the latter three convert the data into information in direct support of management decision making.

Adriaanse et al (1994) define a 'monitoring cycle' as a sequence of related activities that ultimately lead to management decisions and actions and future developments in water management policy. The monitoring cycle includes specifying information needs, defining a monitoring strategy, and network design as well as the more operational activities of sample collection, laboratory analysis, data handling, data analysis, reporting and information utilization described by Ward et al (1990).

For purposes of reviewing the US Clean Water Act (CWA) and the European Water Framework Directive (WFD), a combination of the above categories of monitoring activities is used:

(1) Monitoring strategy – references in the law/directive to specific information objectives of monitoring (as related to management goals) as well as references to how a network of sampling sites should be established;
(2) Data generation – references to how samples should be taken, how samples should be analyzed in the laboratory, and how data should be managed (i.e. stored, retrieved and shared); and
(3) Information generation – references to data analysis methods and reporting contents and formats.

In comparing monitoring implications of the two 'laws', there are times when the authors must 'interpret' the information implied by the law. Other times the law specifically directs the type and form of ambient water quality information needed for its implementation.

**CWA and WFD Monitoring Comparisons**

To compare monitoring 'guidance' in the WFD with the CWA, each law/directive is examined for the information it provides on monitoring activity categories described above. Quotes from the documents are utilized to help articulate the specific guidance provided. Implications of the presence, or absence, of monitoring guidance to monitoring designers are highlighted.

## Monitoring Strategies

Management Goals

The first step in establishing a water quality monitoring system, to support management, is to define the management goals and attempt to connect them to monitoring results. In Section 101(a) of the CWA, goals and objectives are defined as:

> "The objective of this chapter is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."

In the WFD, management goals are defined in 'Whereas' number 19 in the opening justification for the directive:

> "This directive aims at maintaining and improving the aquatic environment in the community. This purpose is primarily concerned with the quality of waters concerned. Control of quantity is an ancillary element in securing good quality and therefore measures on quantity, serving the objective to ensure good quality, should also be established."

Both laws define a need for maintaining and achieving a good condition of the nation's/union's waters. The CWA limits this good condition to the quality status of the waters such as biological, chemical and physical condition whereas the WFD requires recommendations concerning water quality as well as water quantity.

In subsections to Section 101(a) of the CWA, the more specific goals, to achieve the overall legal objective, include:

> "(1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;
> (2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;
> (3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;"

Quotes, from Article 4 of the WFD, suggest specific goals to achieve the overall Directive objectives, for both surface and ground water. In reference to surface water:

(i) "Member States shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water
(ii) Member States shall protect, enhance and restore all bodies of surface water,…. with the aim of achieving good surface water status
(iii) Member States shall protect and enhance all artificial and heavily modified bodies of water,… with the aim of achieving good ecological potential and good surface water chemical status
(iv) Member States shall implement the necessary measures….., with the aim of progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances"

Both laws concentrate on reducing pollutant discharge to achieve management goals. The CWA goes even further and requests that discharge of pollutants be eliminated by a set time. The CWA requests protection of the environment as an interim goal, but the exact nature of the protection is not specifically defined. For example, while 'restore and maintain the chemical, physical and biological integrity' of a nation's waters can be regarded as the management objective of the CWA, Section 101 provides no recommendations concerning the level of improvement sought in the nation's waters. To be able to assess whether the quality of a waterbody is 'restored and maintained', an implication is that changes in water quality over time are measured consistently. What level of water quality permits a waterbody to be defined as 'restored'? The implication is that a 'standard' exists that can be employed to judge if 'restored' conditions have been achieved. At the point of restoration, the management objective switches to 'maintain' water quality – the point where trends become an information goal of monitoring.

The WFD is more definitive when it describes, in the Directive itself, that a 'good surface water status' is composed of ecological and chemical status (Article 2 (18)). A list of priority substances and their marginal (criterion) value is presented in Annex 10. If the pollutants determined in a specific waterbody fall below the criteria values, good chemical status is attained. This WFD management strategy describes use of 'standard' compliance to define the good chemical status. Beyond standard compliance, however, the quality of a waterbody is also defined by determining the good ecological status - by assessing reference conditions the waterbody has to attain (Annex 5). Also, the WFD calls for implementing measures to identify and reverse *trends* in groundwater pollution, thus legally requiring ground water quality assessment to employ a consistent understanding of water conditions over an extended time period.

Section 303(d) of the CWA expresses a need for sound information on water quality as well as a need for standards and TMDLs. The implication is that standard compliance can be measured not only as a sample-by-sample comparison to an acceptable level (the standard), but also to that level over an extended timeframe and across the entire waterbody. In this case, it is important to have a standard include, via a data analysis protocol, how monitoring data, at infrequent time and space scales, will be analyzed to determine standard compliance over large time and space scales.

In the WFD, the management goal is to maintain as well as improve the environment considering the quality and quantity of Europe's surface and ground waters. This implies various goals be measured by the monitoring system. 'Monitoring' has to provide water quality information on standard compliance but it also has to detect trends and the amount of water available. As the WFD aims not only to protect the waters itself but also the aquatic environment, criteria to assess ecosystem characteristics have to be considered in the monitoring program.

If a management goal of the CWA is to attain a water condition to protect fish, shellfish and wildlife, criteria that serve to assess their health have to be established and regularly measured. In this case, the goal of the monitoring design is to determine if the defined standards, that insure a healthy ecosystem, are met. However, no legal guidance is provided for the extent of spatial and temporal monitoring coverage that is sufficient to ensure the standards are met.

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In article 4 of the WFD, measures are requested that prevent deterioration of surface waters. The implication to monitoring is that current conditions are quantified and able to be compared to future conditions in a consistent and comparable manner. The management goal is achieved if there is a constant or improving trend in the sampled data (i.e. no deterioration). Indicators, and criteria that indicate status of surface waters, have to be established. The WFD provides a definition of 'good status' being sought by the Directive, by describing the reference conditions and constituents to sample (Annex 5; Annex 8).

In Article 4, the WFD gives very detailed instructions on what the monitoring goals should be by demanding "measures necessary to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity". The form of information expected from monitoring is clearly articulated.

Network Design

After management information goals are related to monitoring information products, the next step in designing a water quality management program is to determine the sampling frequency, the sampling site location, and the constituents to be sampled to serve the overall information objective. This part of the monitoring system design process is commonly referred to as network design. Network design is not included in the data-to-day operations of a monitoring system (as it is a one-time activity that must take place before samples are consistently collected over time), but it is closely tied to data analysis and interpretation.

*Constituents to sample*

The CWA makes no reference to specific water quality measurements to be made in implementing the law.

On the other hand, the WFD follows up its desire to achieve a "good" ecological and chemical status of all surface waters in the EU by providing, in Annex 5.1.1, recommendations as to which attributes to examine in order to assess the ecological status of rivers. The list of attributes includes biological elements as well as hydromorphological, chemical, and physical elements to support the biological elements. Groundwater chemical status is defined to include conductivity and 'concentration of pollutants' – those constituents that harm human or ecosystem use of the waters.

To evaluate the chemical status of a specific waterbody, the WFD gives direction on which chemical characteristics have to be measured. In Annex 8, an 'indicative list of the main pollutants' can be found. Annex 10 of the WFD, when completed, will contain a list of priority substances (constituents which present a significant risk for the aquatic environment) to be sampled.

The above requirements for ecological status of rivers consider not only the morphological conditions, depth and width variation, but also the river's connection to groundwater and ecological

characteristics such as aquatic flora and fish fauna which serve as indicators of the ecosystems health. Chemical/physical and hydromorphological characteristics serve to support the ecological status assessment.

Normative definitions for the ecological characteristics addressed can be found in Annex V.1.2 of the WFD. The list contains descriptions for a five-class system with gradations of very good, good (management goal), and moderate. The last two gradations are poor and bad. The following descriptions are used to describe the first three classifications. High status has no, or only very minor, anthropogenic alterations from undisturbed conditions; slight variance from undisturbed condition is referred to as 'good status' and moderate variation from undisturbed conditions achieves the label 'moderate status'. These definitions are not sufficient to obtain comparable and consistent information because judgments could differ if different people have to evaluate a good condition. Therefore, class limits have to be defined to make the narrative definitions comparable. Currently, this is done by different European agencies. Intercalibration within Europe will take place at a future date.

*Selection of sampling sites*

The WFD provides directions on how to integrate various categories of monitoring in support of management. The directive requires *surveillance monitoring* of all watersheds as the first step to determine the impact on nation's waters. If waters are identified as being at risk of failing to meet their environmental objectives, *operational monitoring* has to be carried out. Unknown reasons for standard exceedance in specific river segments call for *investigative monitoring* as the last step to obtain management information. In the Annex 5, instructions are given on how to chose sampling sites for each category of monitoring:

> "Selection of monitoring points
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> Surveillance monitoring shall be carried out of sufficient surface water bodies to provide an assessment of the overall surface water status within each catchment or subcatchments within the river basin district. In selecting these bodies Member States shall ensure that, where appropriate, monitoring is carried out at points where:
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> - the rate of water flow is significant within the river basin district as a whole; including points on large rivers where the catchment area is greater than 2500 km2,
> - the volume of water present is significant within the river basin district, including large lakes and reservoirs,
> - significant bodies of water cross a Member State boundary,
> - sites are identified under the Information Exchange Decision 77/795/EEC, and
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> at such other sites as are required to estimate the pollutant load which is transferred across Member State boundaries, and which is transferred into the marine environment."

Surveillance monitoring has to be conducted in all the waterbodies within the European Union to give an overall view of possible problems. Thus, such sampling sites will, of necessity, be more integrator oriented (i.e. representative of physical conditions such as flow and loading) than specific problem oriented. If surveillance monitoring identifies areas which appear to be at high risk of failing to meet environmental goals, Annex 5 Section 1.3.2 specifics the second level of monitoring site location guidance (i.e. operational monitoring). This paragraph, similar to Annex 5, Section 1.3.1.is a detailed description on selecting monitoring sites to conduct surveillance monitoring.

The WFD, by specifying categories of inter-related monitoring efforts, is providing monitoring strategies which track the monitoring process down from overall surveillance monitoring to the monitoring of specific sites where problems occur and the goal of 'good status' is not met. While indicating general criteria for sampling site location, the descriptions are vague concerning details of the specific choice of sampling sites. On the other hand, the general instructions, which cover monitoring within Europe, permit monitoring

system designers to adapt site locations to specific conditions of each watershed. The WFD annex provides a standardized approach to selecting sampling sites that should assist in making the water quality data and information across Europe more consistent and comparable.

The CWA remains silent on selection of sampling points. The monitoring regulations and guidance documents, issued by the various programs within EPA to implement various sections of the CWA, provide the approaches to employ in locating sampling sites. Examples of such guidance are US Environmental Protection Agency (1996 and 1999) and Weyland (2001).

*Sampling frequency*

In Annex 5 1.3.4 of the WFD, detailed instructions concerning sampling frequency are provided in the form of a table. In selecting sampling frequencies, it is also required that estimates of confidence and precision attained by the monitoring system shall be documented in river basin management plans. Sampling frequencies are to be selected to take into account variability in constituents resulting from natural and anthropogenic conditions. This may require additional monitoring during some seasons.

The CWA is silent on sampling frequencies. Again, administrative regulations and guidance are requested program-by-program and implemented state-by-state. This provides considerable flexibility in selecting sampling frequencies, but it also restricts the comparability of data and information from program-to-program and state-to-state.

## Data Generation

After management goals have been defined and specified, and it is known where samples will be taken, what will be measured and how often measurements will be made, the monitoring system is ready to begin operations. As noted earlier, the monitoring system first begins to produce management information by collecting data – data generation. To acquire data, a monitoring system will collect samples, analyze the samples in the laboratory, and store the resulting data in a readily accessible format.

Sample Collection

Sample collection can be considered, operationally, as the first step in the flow of information through the monitoring system. As sampling can be carried out using a number of different methods, obtaining consistent data requires standardization, in some form, of the process of data collection paying particular attention to sampling details, such as sampling techniques, sample preservation and sample transport. Only if these steps are executed in a consistent manner, however, will the resulting data be easily comparable.

In the WFD, no legal advice is provided regarding how sample collection is to be conducted. There are no hints given on what equipment to use, which techniques to apply or if sampling protocols are required. Without a detailed description of the sampling procedure it may be difficult to compare the monitoring data across Europe.

The CWA is also silent on sampling methods. Rather the regulations issued from the CWA appear to require that the methods used to produce management information be documented. For example, 40 CFR 130.7.b requests a description of the methods used to develop the TMDL list.

Laboratory Analysis

Laboratory analysis, as with sample collection, requires numerous steps. At this stage in the monitoring system, the water sample is converted into numbers. The means by which this conversion takes place can influence the numbers, and, over the years, considerable effort has been devoted to insuring accurate numbers are produced during the analysis of samples in a laboratory. There are a number of 'standard methods' available from which designers of monitoring systems can choose. With so many options,

it is increasingly important that the methods selected and employed to generate data be well documented, if not standardized. If changes in methods occur, the change must be documented to insure differences in data, over time, are properly interpreted.

Laboratory analysis methods are not addressed in either the CWA or the WFD. The laws do not require standard analysis methods nor is the need for documentation of the applied techniques expressed. Specification of the requirements for laboratory analysis is left to regulations and guidelines.

Data Handling

Data handling includes data entry, storage, retrieval and development of data records for use in software packages or models. There are two different perspectives with respect to data handling. From one perspective, there is a need to *store* the data once it leaves the laboratory or field measurement instrument. A second perspective comes from those who need consistent data *records* in order to convert the data into useful information in support of water quality management. One group wants to store numbers while the second seeks data records to support statistical software packages or water quality models. The tension between data storage and data record development may require two data management systems.

The CWA is silent on data handling. In the regulations there are efforts to standardize data identification to enhance sharing of the data. For example, in the 2002 Integrated Water Quality Monitoring and Assessment Report Guidance, the author states that: "EPA strongly encourages states and territories to uniformly adopt the National Hydrography Dataset (NHD)". NWIS, STORET, and WATSTORE represent several of the national US water quality data storage systems in operation today.

The WFD requests that initial watershed definition be in a GIS format as the goal is to establish a data storage system which is available all over Europe (Annex 1, ii):

> " ii) Geographical coverage of the river basin district - the names of the main rivers within the river basin district together with a precise description of the boundaries of the river basin district. This information should as far as possible be available for introduction into a geographic information system (GIS) and/or the geographic information system of the Commission (GISCO)."

No mention is made in the WFD regarding how water quality data are to be stored. In the "Handlungskonzept", an additional document to the WFD, it is mentioned that "the Laenderarbeitsgemeinschaft Wasser (LAWA) panel has acquired a concept for a data storage platform supported by the internet. National, as well as local, available data can be used with the help of a modern communication structure." The idea is to implement a cross-national information storage system. Thus, data storage is being addressed during implementation of the WFD.

## Information Generation

The water quality data, hopefully stored in a form readily available, can now be analyzed and interpreted to produce information in support of management. This phase of the monitoring system, regarded as information generation, is composed of data analysis, reporting and information utilization.

Data Analysis

Data analysis can be carried out in different ways - graphical means as well as statistical means and models all have their place in converting water quality data into information, depending on the information sought.

In the CWA, no recommendations are made regarding which methods to use to analyze water quality data. The law also remains quiet concerning the process of data analysis as the focus is on the information expected to be produced by monitoring. Griffiths et al. (2001) surveys the current use of data analysis

methods and notes the lack of consistency in both the peer reviewed literature and monitoring guidance documents.

In the WFD, no recommendations are made on how to analyze data that serve to prove standard compliance. However, concerning trend detection in ground water quality, the WFD specifies the following in Annex 5.2.4.4:

> "2.4.4. Identification of trends in pollutants
>
> Member States shall use data from both surveillance and operational monitoring in the identification of long-term anthropogenically induced upward trends in pollutant concentrations and the reversal of such trends. The base year or period from which trend identification is to be calculated shall be identified. The calculation of trends shall be undertaken for a body or, where appropriate, group of bodies of groundwater. Reversal of a trend shall be demonstrated statistically and the level of confidence associated with the identification stated."

In the quote it is stated that the reversal of a trend has to be proven with statistical methods, yet a specific method is not recommended. Griffiths et al. (2001) note the differences in information obtained, from the same data set, when different data analysis methods are used. The same problem occurs when different confidence levels are used within the same statistical method.

Reporting

Reporting forces those designing and operating monitoring systems to synthesize, interpret, and present the results obtained from data analysis in a manner that satisfies the original information goals. There are various ways to present the acquired information, such as via narrative descriptions or through graphical means.

In the CWA, as well as in the WFD, different recommendations are made on how to report information obtained via monitoring. The WFD requests reporting to the Commission (Article 7) through the River Basin Management Planning process. In Annex 5 of the WFD, the requirements of such a report are described in detail. With the objective of achieving 'good status' in all surface and ground waters, the reporting focus is defined. 'Good status' for surface waters is composed of 'good chemical status' (low levels of pollutants) and 'good ecological status'. 'Ecological status' is measured against reference criteria for the particular ecosystem (e.g. an alpine river, a lowland lake, etc.) - a technical description of a theoretical pristine state based on biology, hydromorphology and chemistry. 'Good ecological status' is set as the acceptable deviation from this standard. The development of the River Basin Management Plan will include an analysis of the characteristics of the River Basin such as its location and ecoregions, the environmental impacts of human activity within it including estimation of point source and non point source pollution and an economic analysis of water use within the basin. Based on this information, a summary of the programs of measures taken to meet the requirements of the WFD will be part of the report. Additionally it is required that progress be assessed since the previous report was published.

The River Basin Management Plan focuses on reporting within natural boundaries of river basin districts and not within jurisdictional boundaries. This is a new approach - to consider the whole watershed area and provide consistent information rather than report by political jurisdiction. The law itself goes into detail about what information the report has to include, taking into account the different Appendices of the WFD which state clearly which topics have to be addressed in the River Basin Management Plan.

There are three different sections of the CWA, requiring reporting, that will be considered in this analysis. The three sections call for different reports such as the State Assessment Report on non point source pollution (319), the State Report on Water Quality 305(b), and the TMDL list 303(d).

Reporting requirements of Section 319 includes the following information.

1. List of waters which don't match standards or management goal due to nonpoint source pollution;
2. List of nonpoint sources which lead to not meeting the standards;
3. Description of the process to find the best management practice; and
4. Description of programs implemented to meet standards.

Reporting requirements of Section 305 (b) include the following:

1. Description of water quality;
2. Analysis of the extent to which waters meet the management goals; and
3. List of means taken to achieve the management goals.

Section 303 (d) reporting requires:

1. List of TMDLs;
2. List of waters where management goals are not met; and
3. List of waters where standards are not met.

While requiring reports with broad categories of information, the legal descriptions do not provide detail regarding specific contents of the reports. It is left to regulations and guidelines, such as the 'Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305(b) Reports and Electronic Updates)', published by the EPA, to provide detail contents

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Section 305(b) requires states to identify the contribution of non-point sources to water quality impairment. It also calls for an analysis of the social and economic costs and benefits of achieving the goals of the Clean Water Act. This section specifies that states submit reports describing water quality conditions to the US Environmental Protection Agency (EPA) every two years. Section 305(b) also requires that EPA summarize the reports submitted by the states and other jurisdictions and convey goals of the CWA. These assessments are a major source of information for identifying the waters and pollutants contributing to impairments that have to be included in the 303(d) list. After preparing a list, 303(d) requires the states to implement TMDLs, which are the maximum daily loads of pollutants a river can carry and still meet the standards. Sections 303(d), 319 and 305(b) each require a list of waters where standards and goals are not met and a description of the means to be employed to achieve the goals. Only considering the law, 305(b), 303(d) and 319 appear to be very similar, the differences between those only become obvious if additional guidance documents such as regulations and guidelines are considered. Efforts are underway to consolidate the reporting requirements, such as that reported by Weyland (2001).

The reporting differences between the WFD and the CWA are (1) watershed versus state boundary approach and (2) very detailed definition of reporting requirements in the WFD versus basic reporting requirement definition in the CWA. The different approaches have a major influence on the contents of the report submitted to the officials. If the law does not provide guidance, many decisions are left to the states with the effect that different methods may be employed to describe and assess the nation's waters resulting, perhaps, in less comparability and consistency across states. On the other hand, it will be easier to consider variations in location and geography.

In the WFD an effort is made to consider the natural variations and still provide reports which are comparable by grouping waterbodies together for the purpose of identical characterization. (Annex 1).

The WFD provides guidance on how monitoring results should be presented in reports. To illustrate, recommendations are made in Annex 5.1.4.2 on how to present water quality information. The results from monitoring concerning the ecological status are to be presented by mapping each river section in accordance to the color code shown below:

Ecological Status Classification Color Code:

| | |
|---|---|
| High | Blue |
| Good | Green |
| Moderate | Yellow |
| Poor | Orange |
| Bad | Red |

**Summary and Conclusions**

To organize the comparisons of the CWA and WFD from the perspective of providing guidance for monitoring, the process of monitoring was broken into eight, highly integrated categories of activities. Table 1, using categories of monitoring activities, presents a brief overview of the monitoring guidance comparisons while Table 2 presents a more condensed summary of findings.

If it is assumed that all activities must be performed in a well defined and documented manner in order to produce consistent and comparable water quality information, the findings in Table 1 note considerable lack of legal guidance on how to use monitoring science and technology. Selection of monitoring methods, at many points along the flow of water quality information, is left to regulatory definition and/or ad hoc decisions by those performing the specific tasks.

Both the CWA and WFD specify management objectives and reporting required – 'bookends' of the water quality monitoring system. The law and directive differ greatly in the detail provided in between. The WFD addresses network design and sample collection, but is silent on laboratory methods, data management, and techniques to perform data analysis. The WFD does provide guidance on how to interpret data relative to ecological status and how to report the results. The CWA is silent on network design, sample collection, laboratory analysis, data management, and data analysis. It also does not specify how information is to be reported, only that a report is to be prepared.

Comparing a 1972 law, with a 2000 directive, may be considered by some to be comparing apples and oranges. Thirty years of thinking have evolved regarding how monitoring should be conducted in support of management decision-making. In many ways, the ability of the WFD to provide monitoring guidance is a reflection of the progress made in the 'science' of monitoring for management purposes.

Both the CWA and WFD address water quality management across a continent scale. Thus, the hydrological, biological and geological conditions vary considerably across states and countries. A 'standardized' approach to monitoring may not permit the adjustments to local conditions deemed critical by local water managers. This is another argument for more freedom in monitoring strategies and methods. The WFD appears to address this fact by calling for developing management plans that embody a common framework that should permit comparability across Europe.

The WFD implies that water quantity and quality monitoring are highly integrated activities. Under the CWA, Section 101(g) explicitly states that states reserve the right to allocate quantities of water within states. Such statements support the view that water quality monitoring is quite separate from traditional streamgaging in the US. Other parts of the CWA, however, imply that water quantity and quality must be integrated, such as in Section 303 when TMDLs, a 'load' calculation, is discussed. Furthermore, in contrast to the CWA, which only considers the water itself, the WFD establishes a guideline that takes into consideration not only the waters but also the broader aquatic ecosystem.

| Water Quality Legal Framework<br>_____<br>Water quality Information System Phases | United States<br>Clean Water Act | European<br>Water Framework Directive |
|---|---|---|
| 1) Monitoring Strategy | **Management Goal:**<br>Section 101: Goals and policy: defines goals which have to be achieved<br><br>**Network Design:**<br>Silent on how to chose sampling sites, monitoring frequency, pollutants to sample | **Management Goal:**<br>(19): Decalares the overall goals of the WFD<br>Article 4: Environmental objectives:<br>lists the objectives of the WFD<br>**Network Design:**<br>Annex 5.1.1: list of attributes to examine to achieve good ecological status<br>Annex 5.1.2: Normative definitions for ecological characteristics<br>Annex 5.1.3: Selection of monitoring sites<br>Annex 5.1.3.4. Monitoring frequency<br>Annex 8: Constituents to sample<br>Annex 10: list of priority substances |
| 2) Data Generation | **Sample Collection:**<br>Silent on sample collection methods<br>**Laboratory Analysis:**<br>Silent on selection of laboratory analysis techniques<br>**Data Handling:**<br>Silent on how data are to be managed/shared | **Sample Collection:**<br>Specifies sampling methods for biological measurements; silent on selection of chemical sampling techniques<br>**Laboratory Analysis:**<br>Silent on selection of laboratory analysis techniques<br>**Data Handling**:<br>Annex 1, ii): WFD requires a data storage system but is silent on how to store water quality data |
| 3) Information Generation | **Data Analysis:**<br>Silent on how data are to be analyzed to obtain information.<br>**Reporting:**<br>Section 305(b) says report will be provided and indicates frequency of reporting, but does not say how information in report is to be develop.<br>Section 303(d): submission of TMDL lists to the administrator;<br>Section 319(a): state assessment reports | **Data Analysis:**<br>Silent on which methods to use to analyze data.<br>Provides guidelines on how to interpret data relative to definitions of water quality status.<br>Annex 5.2.4.4: trend detection requires statistical methods<br>**Reporting:**<br>Article 13**:** requires River Basin Management Plan (RBMP);<br>Annex 8: describes elements and information to be included in the RBMP and updates.<br>Article 15: specifies distrubtion of reports, frequency of reports, and need to include anlyses required under Articles 5 and 8<br>Annex 5: Classification and presentation of ecological status with the help of a color code to make results comparable and to define whether goals (at least good status) are met. |

**Table 1.** Overview of Specific Comparisons of Monitoring Requirements.

| | CWA | WFD |
|---|---|---|
| Management Goal | x | xxx |
| Network Design | o | xxx |
| Sample Collection | o | o |
| Laboratory Analysis | o | o |
| Data Handling | o | xx |
| Data Analysis | o | x |
| Reporting | x | xxx |

o- law remains silent concerning this aspect of the monitoring system
x- law mentions the aspect but lacks specification for monitoring purpose and does not require specific methods
xx- law mentions the aspect and required methods but lacks connection towards monitoring
xxx- aspect is mentioned, recommendations for monitoring are defined and methods are described

**Table 2.** Summary of Results

Both the CWA and WFD are silent on guidance for data management and specific statistical methods to employ in computing the desired trends in water quality data. The lack of data management 'standardization' prevents ready sharing of data that is needed under the more innovative integrated watershed management efforts. In the US 'water monitoring councils' are forming at the national, state and watershed levels, often for the express purpose of developing a means of sharing water quality data. Such sharing requires documentation of the methods used to obtain data and information (i.e. meta data) and a more common way to store the data electronically. The National Water Quality Monitoring Council, through the efforts of its Methods and Data Comparability Board, are moving toward the standardization that will permit ready sharing of water quality data. The webpage of the NWQMC is: http://water.usgs.gov/wicp/acwi/monitoring/

The increasing trend to place monitoring guidance in water quality management laws provides a challenge to those who design water quality monitoring systems. Hopefully, this paper, while attempting to quantify the legal monitoring guidance, has helped to define the need for monitoring designers to consider the science of their profession and work toward more consistency and comparability in the information produced by monitoring efforts.

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